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Skull Base Approaches for Vertebro-Basilar Aneurysms

Renato J. Galzio[1,2], Danilo De Paulis[2] and Francesco Di Cola[1]
[1]*Department of Health Sciences (Neurosurgery), Medical School of the University of L'Aquila, L'Aquila*
[2]*Department of Neurosurgery, "San Salvatore" City Hospital, L'Aquila, Italy*

1. Introduction

Posterior circulation aneurysms are deeply embedded in very limited subarachnoidal spaces surrounded by heavy bony structures and in intimate relationship with both the brainstem and its vasculature. These lesions, if compared to anterior circulation aneurysms, more frequently present large dimensions, intraluminal thrombosis and sclerotic changes of the sac and of the parental artery. Both vertebro-basilar (VB) aneurysms' intrinsic characteristics and their location make every kind of treatment a challenge. Endovascular therapy has gained a special and effective role in the management of these lesions, but it is not always indicated or possible, hence surgery still represents the best therapeutic option, especially in case of complex and giant lesions. We have revised our casuistic from January 1990 to December 2010 to discuss the approaches that have been used in the surgically treated 150 vertebro-basilar aneurysms.

2. Clinical materials and methods

2.1 Patient population

From January 1990 to December 2010, 1056 patients harbouring 1193 aneurysms have been operated by the senior author (RJG) up to a total of 1114 surgical procedures. 118 of the patients harboured multiple aneurysms that have been treated in single or multiple surgical sessions, or with combined treatments (surgical for one or more lesions and endovascular for others). 144 patients were surgically treated for VB lesions; 4 of them presented 2 different aneurysms in the posterior circulation and 1 of them showed 3 lesions all located in the VB system. 10 patients harboured at least 1 VB aneurysm together with 1 or more aneurysms located in the anterior circulation. A total of 150 aneurysms of the posterior circulation have been operated; 48 lesions showed a diameter larger than 2.0 cm: 24 of them (16%) presented a diameter larger than 2.5 cm (giant aneurysms) and 24 of them (16%) presented a diameter between 2.0 cm and 2.5 cm (very large aneurysms). Clinical presentation of our patients (144) with posterior circulation aneurysms was hemorrhagic in 95 cases (63.3%) and not hemorrhagic in 49 subjects (32,6%). Because of the introduction of the endovascular treatment, this series is not homogeneous; endovascular therapy began to be routinely used in our department since the year 2000, thereafter, the number of surgically treated patients has progressively reduced, while the percentage of surgical procedures for complex aneurysms has relatively increased. From January 1990 to December 1999, 94 patients harbouring 98 VB aneurysms have been operated; 27 aneurysms (27.5%) presented a diameter larger than 2.0 cm. Only 50 patients harbouring 52 VB aneurysms were operated after January 2000, but 21 lesions (42%) were very large or giant aneurysms. In the present study we have only considered lesions treated by direct microsurgical approach, hence cases treated exclusively by endovascular approach or by extra- to intra-cranial bypass and trapping (2 giant aneurysms of the distal prejunctional vertebral artery) have been excluded. Table 1 summarizes location and characteristics of the lesions. Table 2 summarizes the number of treated aneurysms before and after the introduction of endovascular therapy in our institute. Table 3 summarizes the outcomes in the presented series.

	N° of Aneurysms	*Giants (Ø ≥ 2.5 cm)*	*Very large (2cm< Ø <2.5cm)*
Basilar tip	75	9	12
PCA/SCA	16	2	3
Midbasilar (AICA)	12	2	3
Vertebro-basilar Junction	13	3	2
Vertebral (PICA)	22	3	2
Distal branches	12	5	2
Total	**150 (100%)**	**24 (16%)**	**24 (16%)**
		Total (Giant & Very large): 48 (32%)	

Table 1. Locations and characteristics of the 150 treated aneurysms.

	N° of Patients	*N° of Aneurysms*	*N° of Giant & Very Large Aneurysms*
Global (1999-2008)	**144 (100%)**	**150 (100%)**	**48 (32%)**
First period (1990-1999)	**94 (65,2%)**	**98 (65,3%)**	**27 (27,5%)**
Last period (2000-2008)	**50 (34,8%)**	**52 (34,7%)**	**21 (42%)**

Table 2. Number of treated aneurysms before and after the introduction of the endovascular therapy in our Institute.

	N° of Patients	*No or Minimal deficit*	*Moderate deficit*	*Severe deficit or Vegetative*	*Death*
Global	**144**	**94 (65,3%)**	**28 (19,5%)**	**10 (6,9%)**	**12 (8,3%)***
Unruptured Aneurysms**	**49**	**33 (67,4%)**	**7 (14,3%)**	**5 (10,2%)**	**4 (8,1%)**
Giant Aneurysms	**24**	**15 (62,6%)**	**3 (12,5%)**	**2 (8,3%)**	**4 (16,6%)***

Table 3. Outcome of the presented series (* 2 Giants aneurysms operated in grade IV Hunt-Hess scale for impending life hematoma; ** 10 Giant aneurysms comprised).

2.2 Surgical procedure

Successful direct surgical treatment of VB aneurysms, specially of complex ones, is mainly based on the choice of an adequate approach and on the application of specific surgical adjuncts.

Approaches have to provide a wide working room, short working distance, straight access and the possibility of handling the lesion from different points of view with minimal manipulation and retraction of critical perilesional neurovascular structures; exposure of the parental artery and efferent vessels (to achieve eventual temporary occlusion), complete exposure of the implant base (to get best clip positioning) and wide exposure of the aneurismal sac, at least of its proximal portion, (to manipulate the lesion from different directions) have to be achieved through an adequate access to the lesion. These goals are, in most instances, achieved by performing skull base approaches, which are essentially based on the principle of removing as much bone as possible to minimize retraction and manipulation of critical perilesional structures. We have used standardized approaches and the choice was essentially performed taking into consideration the location and the specific intrinsic features of the lesion (Figure 1).

Many intraoperative surgical techniques may result truly effective in the treatment of VB aneurysms; temporary clipping or trapping of the parental vessel allows, in many instances, an effective decompression of the aneurismal sac and the possibility to expose the implant base of the lesion which has to be dissected from perforators and efferent arteries before definitively clipping [Taylor, 1996; Baussart, 2005]; the “stacking-seating” technique, which consists in the use of differently shaped and sized clips which are progressively apposed and eventually removed until obtaining definitive exclusion of the sac, may prevent injuries to perforators and perilesional vasculature and may avoid constriction of flow through the parent vessel [Levy, 1995; Giannotta, 2002]; intraluminal decompression is often necessary to achieve a definitive exclusion of the aneurysm, and in case of thrombosed lesions it can be obtained using the ultrasonic aspirator [de Oliveira, 2009]; the use of multiple, variously shaped and sized clips apposed in embricated way (“tandem” clipping, “dome” clipping) results especially helpful when dealing with giant and very large VB aneurysms [Lawton, 1998; Kato, 2003; Sharma, 2008]; bipolar coagulation to reconstruct the parental vessels in wide based lesions; definitive trapping has been used in 2 cases of massively thrombosed aneurysms located in the distal branches, one in the superior cerebellar artery (SCA) and the other in the P2 tract of the posterior cerebral artery (PCA); aneurismorraphy has been used in one case of giant partially thrombosed aneurysm of the P1 tract of the left PCA [Hosobuchi, 1979; Samii, 1985].

The application of other intraoperative additional methodologies also turned out to be especially useful in the treatment of VB aneurysms; intraoperative doppler to test patency of afferent vessels after clipping has been used in nearly every case [Akdemir, 2006; Kapsalaki, 2008]; more recently, we have used intraoperative fluoroangiography [Raabe, 2005; Dashti, 2009] and endoscopic assistance to microneurosurgery, which has revealed particularly effective in the treatment of lesions located in the distal portion of basilar artery [Taniguchi, 1999; Kalavakonda, 2002; Galzio and Tschabitscher, 2010].

We have operated on 144 patients harbouring 150 VB aneurysms. Four of these subjects harboured 2 aneurysms in the VB system and one patient harboured 3 posterior circulation aneurysms: two patients harbouring 2 aneurysms respectively located in the top of the basilar artery and in the junction between basilar artery (BA) and SCA were operated on through a fronto-temporo-orbital (FTO) approach (one of these patients also harboured an internal carotid artery/posterior communicating artery aneurysm); one subject harbouring a basilar top and PCA (P2) aneurysm was operated at first through a pterional approach and successively through a subtemporal controlateral approach; one patient harbouring a BA/SCA aneurysm and a posterior inferior cerebellar artery (PICA) aneurysm underwent a pterional approach and successively a far lateral approach; the patient with 3 lesions was operated at first through a FTO approach (to clip a basilar top and a BA/SCA aneurysms) and successively through a far lateral controlateral approach to treat a PICA aneurysm; none of multiple aneurysms was a giant one.

Thereafter, we have performed 147 procedures to treat 150 posterior circulation aneurysms in 144 patients.

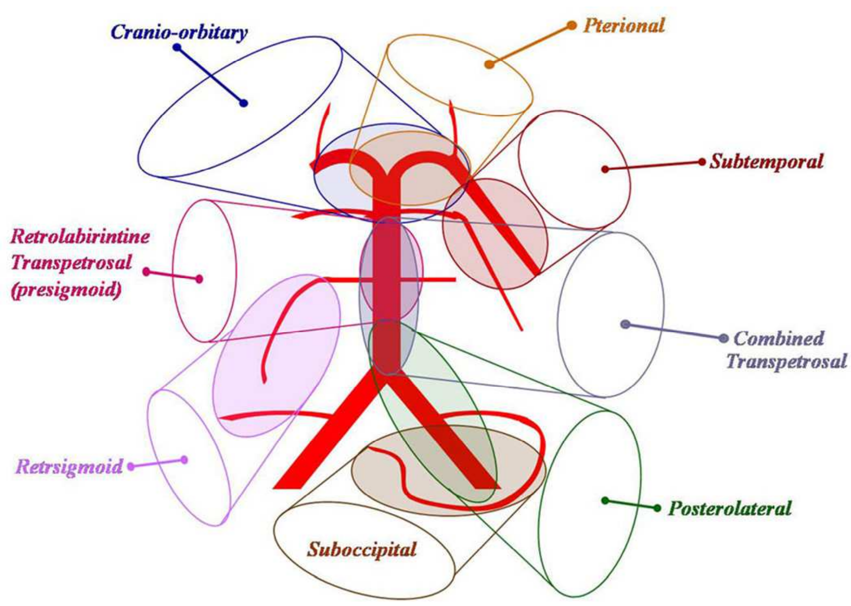

Fig. 1. Schematic drawing defining the surgical approaches used for 150 posterior circulation aneurysms, essentially based on their location.

2.2.1 Pterional approach

The pterional approach has been used in 75 patients harbouring lesions located in the distal portion of the basilar artery: 65 lesions were located in the basilar artery bifurcation/P1 tract (basilar top) and 10 lesions were located in the BA, at the level of the origin of the SCA to the origin to the PCA (PCA/SCA aneurysms). 4 of the basilar top aneurysms that we treated through the pterional approach, were giant ones. The pterional approach has been essentially used for medium sized, not very complex lesions (Figure 2).

We prepare the pterional approach in the submuscular fashion, as described by Spetzler [Coscarella, 2000; Oikawa, 1996]. In any case a drilling of the sphenoid wing was accomplished until opening the sphenoid fissure and drilling the orbital crests; an extradural anterior clinoidectomy and optic canal unroofing was also accomplished to have the possibility to achieve a wider mobilization of the optic nerve (ON) and of the internal carotid artery (ICA) during the operation [Sato, 2001; Noguchi, 2005]. After opening the dura, the sylvian fissure was widely dissected and basal cisterns exposed [Yasargil, 1976]. Two main surgical corridors allow access to the distal portion of the basilar artery; the first, between ON and ICA, is usually narrow and it has been rarely used; the second, between ICA and 3rd cranial nerve (CN), is normally wider and it has been used in most instances: this corridor may be further widened by incising the attachment of the tentorial notch (Figure 3).

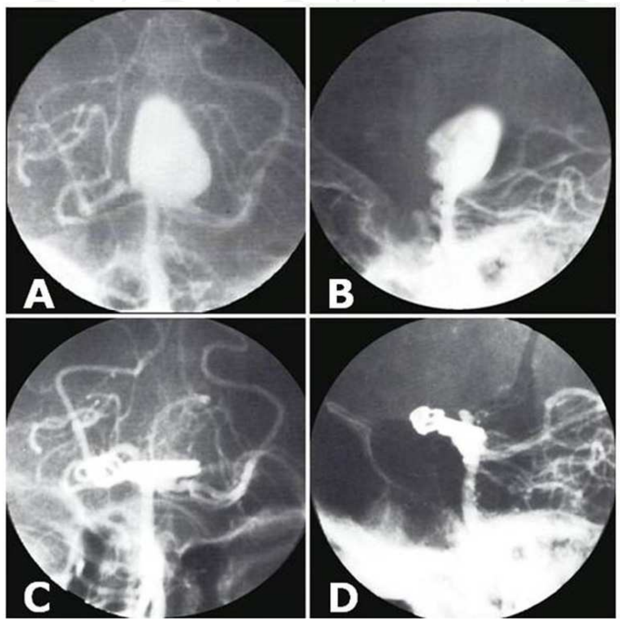

Fig. 2. Preoperative (A,B) and postoperative (C,D) angiography of a basilar tip aneurysm treated through a pterional approach.

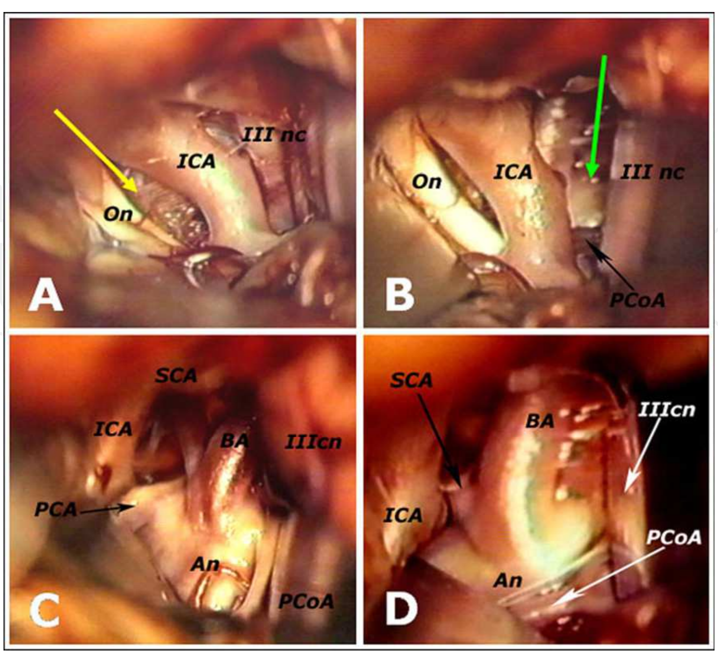

Fig. 3. Intraoperative images: after the preparation of a right pterional approach, the dura is opened and the sylvian fissure widely dissected, exposing the structures located in the

anterior basal cisterns: the surgical corridor (yellow arrow) between the optic nerve (ON) and the internal carotid artery (ICA) is normally narrower than the corridor (green arrow) located between the internal carotid artery and the third cranial nerve (III CN) (A,B); the corridor between ICA and III CN can be further widened by incising the attachment of the tentorial notch to better expose the basilar artery (BA) with its terminal branches, posterior cerebral artery (PCA) and superior cerebellar artery (SCA) and the implant base of the aneurysm (An); the posterior communicating artery (PCoA) remains in the right infero-lateral sector of the operative field (C,D).

Sometimes, a short posterior communicating artery (PcoA) inhibits the exposure of the distal portion of the BA and it has to be sectioned to allow a vision of the aneurysmal implant base [Yasargil, 1976; Inao, 1996]; when the aneurysm has a wide neck, it may be useful to prepare the parental vessel in a way to apply a temporary clip, if necessary in a safe location without endangering perforators or other adherent vessels (Figure 4).

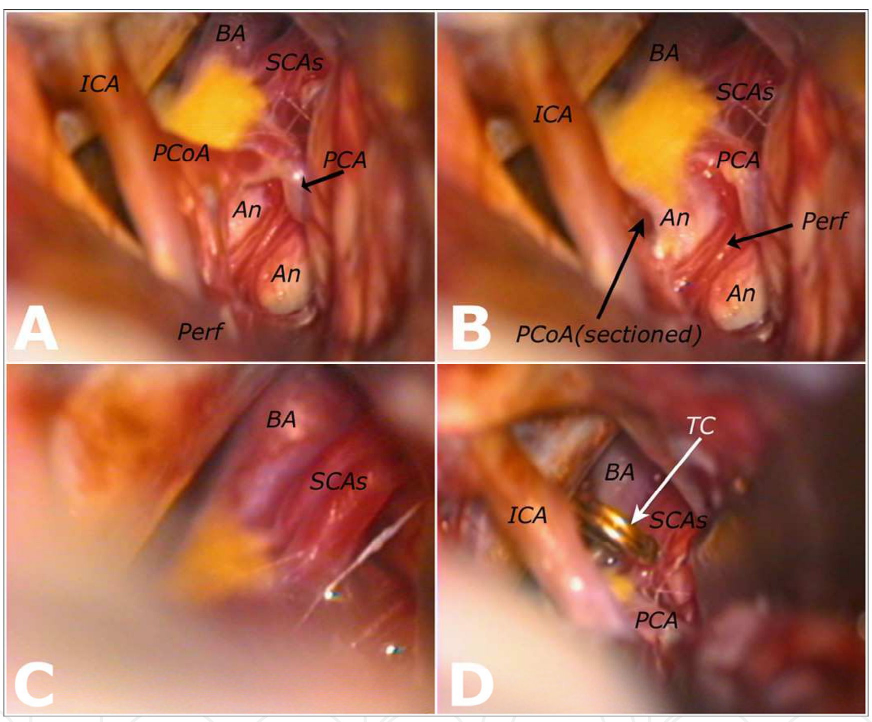

Fig. 4. Intraoperative images (same case of Fig.3): a short posterior communicating artery (PCoA) sometimes inhibits the exposure of the distal portion of the basilar artery (BA) (A); it may be sectioned, avoiding damage to perforators, to get a sight of the implant base of the aneurysm (An) (B); control of the parental basilar artery (BA) and of its distal branches, superior cerebellar artery (SCA) and posterior cerebral artery (PCA), has to be achieved (C); a temporary clip (TC) may be placed in a safe position (D).

The use of differently sized and shaped clips to perform transitory and definitively clipping is, in case of wide based lesions, the only way to preserve perforators (Figure 5); after definitive clipping, the sac has to be opened and evacuated to confirm a complete exclusion (Figure 6). For aneurysms of the distal portion of BA located below the posterior biclinoidal line (Figure 7), a posterior clinoidectomy has to be performed to visualize the parent vessels and the implant base [Fujitsu, 1985; Dolenc, 1987] (Figure 8).

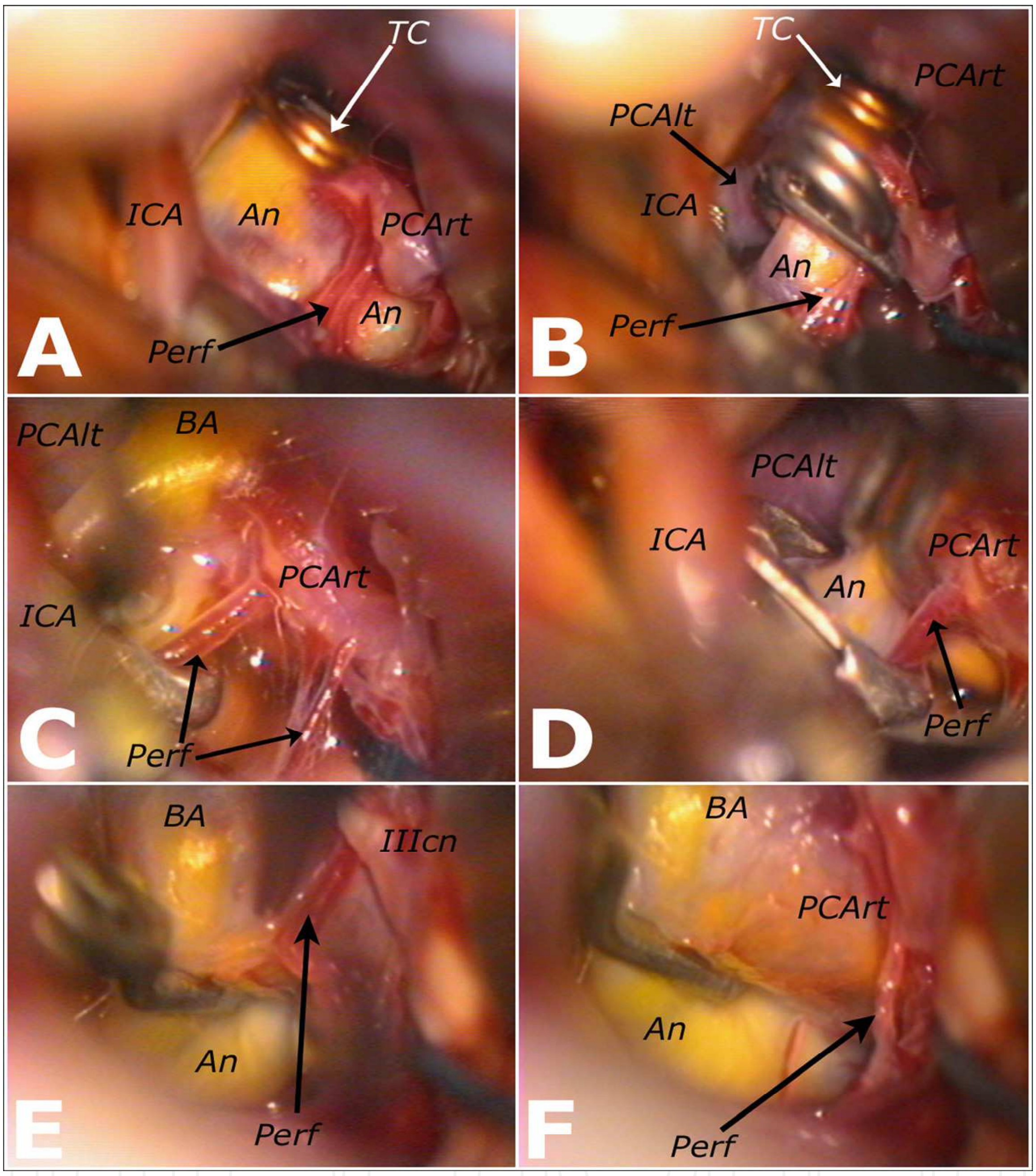

Fig. 5. Intraoperative images (same case of Figs.3 and 4): the temporary clip (TC) is applied on the basilar artery (BA) to reduce the intraluminal pressure into the aneurysmal sac and differently shaped and sized clips are progressively apposed and removed, both to avoid damage to perforators (Perf) and efferent arteries and to avoid constriction of flow through the parent vessel, until obtaining a definitive exclusion of the aneurysm ("stacking-seating technique") (A,B,C,D); the aneurysm has been definitively excluded with a bayonet shaped clip, preserving integrity of the left posterior cerebral artery (PCAlt), of the right one (PCArt) and of perforators, which have been progressively separated from the aneurysmal sac; the temporary clip initially placed on the basilar artery has been removed (E,F).

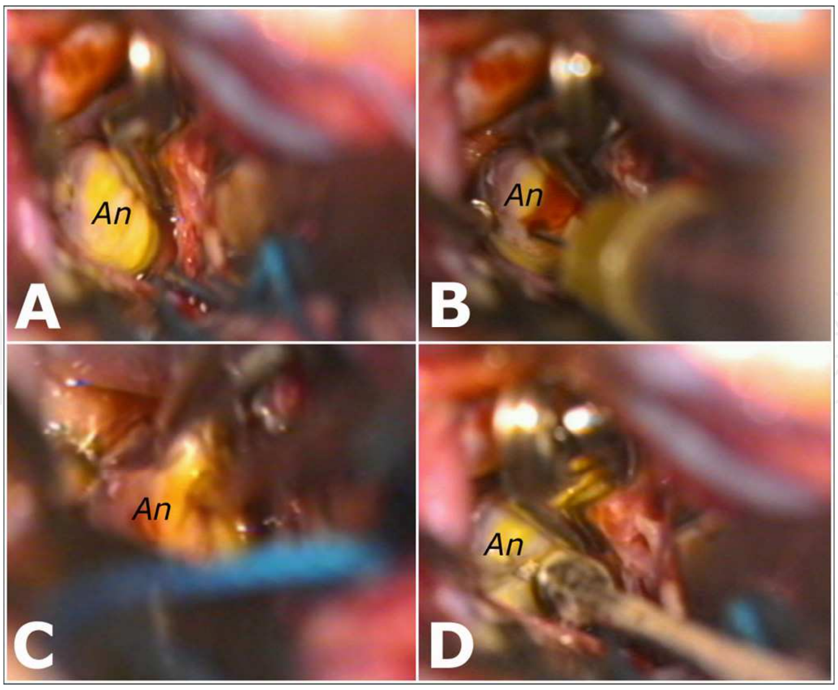

Fig. 6. Intraoperative images (same case of Figs.3, 4 and 5): the definitive clip has been reinforced with a second bayonet shaped clip applied parallel (A) and the aneurysmal sac is evacuated by puncture (B), shrunk with the bipolar coagulator (C) and opened with a micro-knife (D).

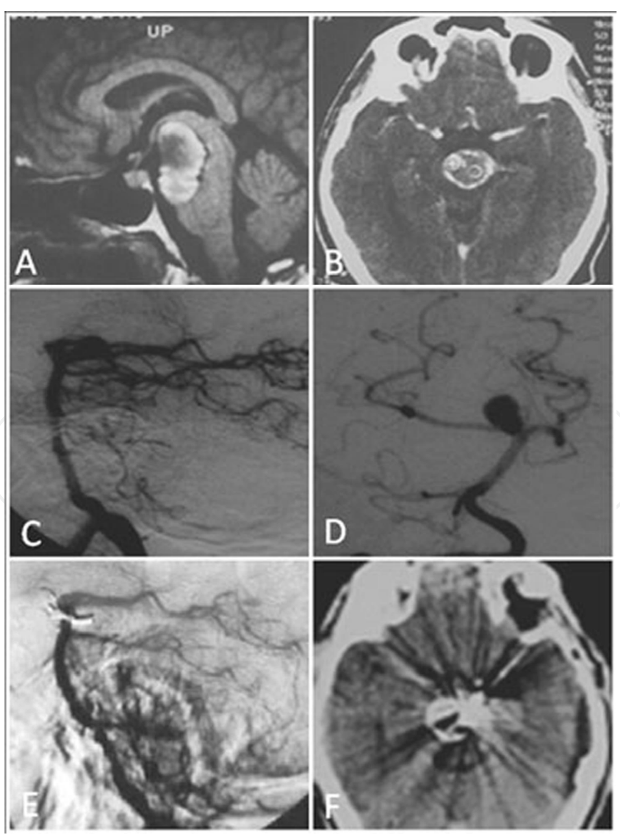

Fig. 7. Preoperative MRI (A), preoperative CT scan (B), preoperative angiography (C,D), postoperative angiography (E) and postoperative CT scan (F) of a very large massively

thrombosed aneurysm with the implant base located low with respect to the posterior biclinoidal line, in the distal portion of the basilar artery between the origin of the right superior cerebellar artery and the origin of the right posterior cerebral artery; this lesion was approached through a right pterional approach.

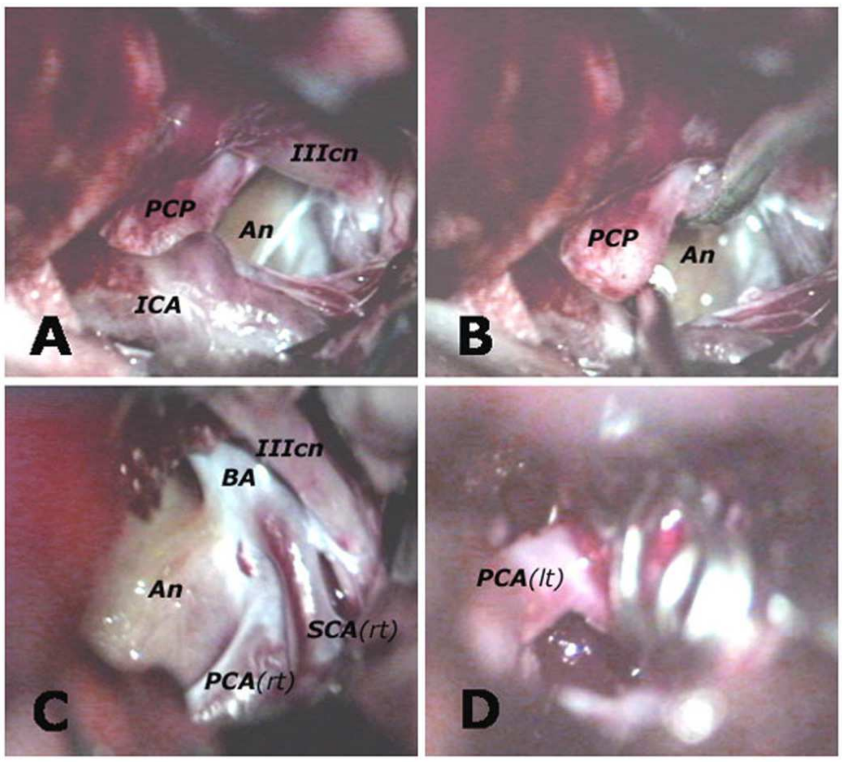

Fig. 8. Intraoperative images of the same case of Fig.7: the posterior clinoid process (PCP) limits the inspection of the implant base of the aneurysm (A,B);after resection of the PCP, the basilar artery (BA) with its right (rt) distal branches, superior cerebellar artery (SCA) and posterior cerebral artery (PCA), and the proximal portion of the aneurysm are completely displayed (C); after definite clipping of the aneurysm, also the left (lt) PCA is clearly patent (D).

2.2.2 Fronto-temporo-orbital approach

The fronto-orbito-temporal (FTO) approach has been used in 10 cases: 5 giant aneurysms located in the basilar top, 5 SCA/PCA aneurysms, among which 2 were giant lesions.

We usually prefer to perform the FTO approach as a two-piece, non osteoplastic craniotomy [Zabramski, 1998; Lemole, 2003; Galzio, 2010]. The FTO approach has been essentially used for more complex and very large and giant aneurysms; in effect this approach allows a very wide working room, with the possibility to use three different surgical corridors: not only the normally used two corridors, the first between ON and ICA and the second between ICA artery and the third cranial nerve, which are widely exposed, but it is also possible to open the anterior border of the tentorium to work laterally to the third cranial nerve. This third surgical corridor is especially useful to treat complex aneurysms of the distal BA directed laterally or mainly implanted in the P1 segment of the PCA (Figures 9 and 10).

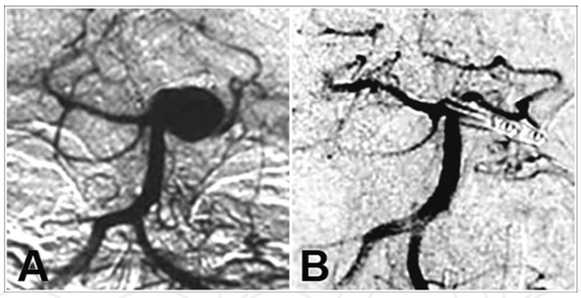

Fig. 9. Preoperative (A) and postoperative (B) angiography of a very large basilar tip aneurysm directed toward the left side, treated through a left fronto-temporo-orbital approach.

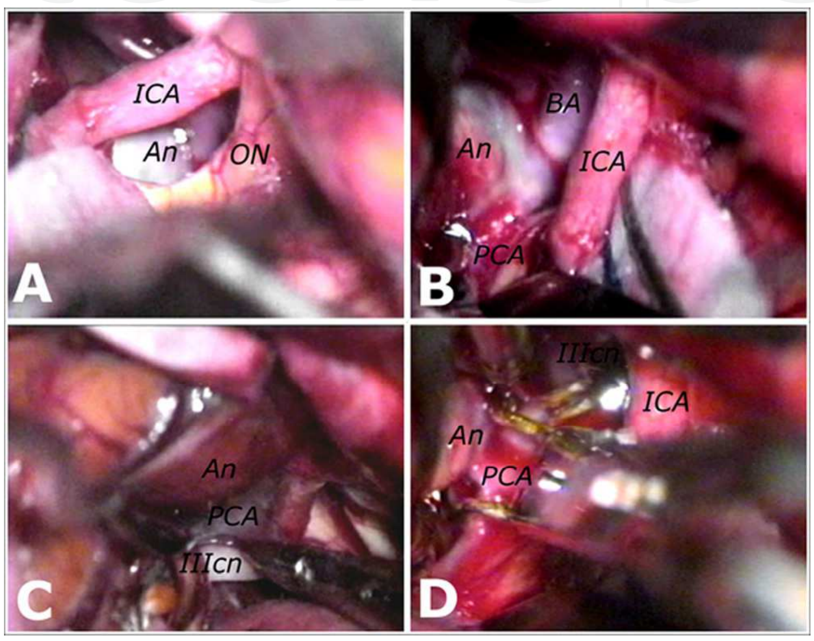

Fig. 10. Intraoperative images of the same case of Fig 9: the aneurysm (An) is visible in the surgical corridor between optic nerve (ON) and internal carotid artery (ICA) (A); changing the direction of view, the aneurysm, the parental basilar artery (BA) and the posterior cerebral artery (PCA) are visualized (B); after the incision of the tentorial edge, the implant base of the aneurysm at the angle between the basilar artery and the posterior cerebral artery is better evidentiated (C); the aneurysm is clipped working laterally to the third cranial nerve (D).

2.2.3 Fronto-temporo-orbito-zygomatic approach

The fronto-temporo-orbito-zygomatic (FTOZ) approach has been used in 5 cases of basilar top aneurysm, including a giant one, and in 1 case of BA/SCA aneurysm.

This approach is performed in a two-pieces fashion, exactly as FTO, by adding the resection of the zygomatic arch which is left attached to the masseter muscle [Galzio, 2010]. This approach has been used for lesions located very high with respect to posterior biclinoidal line [Jennett, 1975; Kasdon, 1979; Ikeda, 1991; Bowles, 1995; Sindou, 2001] because both zygomatic arch and orbital roof translocation together allow the complete observation of the implant base and the possibility of manipulating these aneurysms from different directions (Figures 11 and 12).

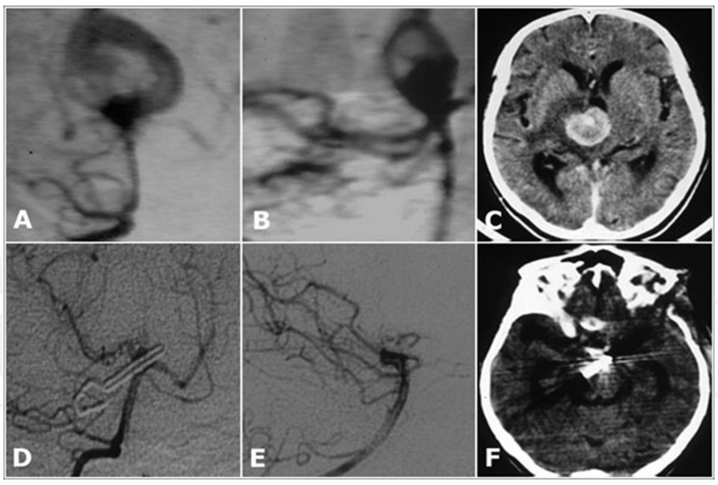

Fig. 11. Preoperative angiography (A,B), preoperative CT scan (C), postoperative angiography (D,E) and postoperative CT scan (F) of a giant basilar tip aneurysm, located high with respect to the posterior biclinoidal line, embedded into the third ventricular room, exposed through a fronto-temporo-orbito-zygomatic approach.

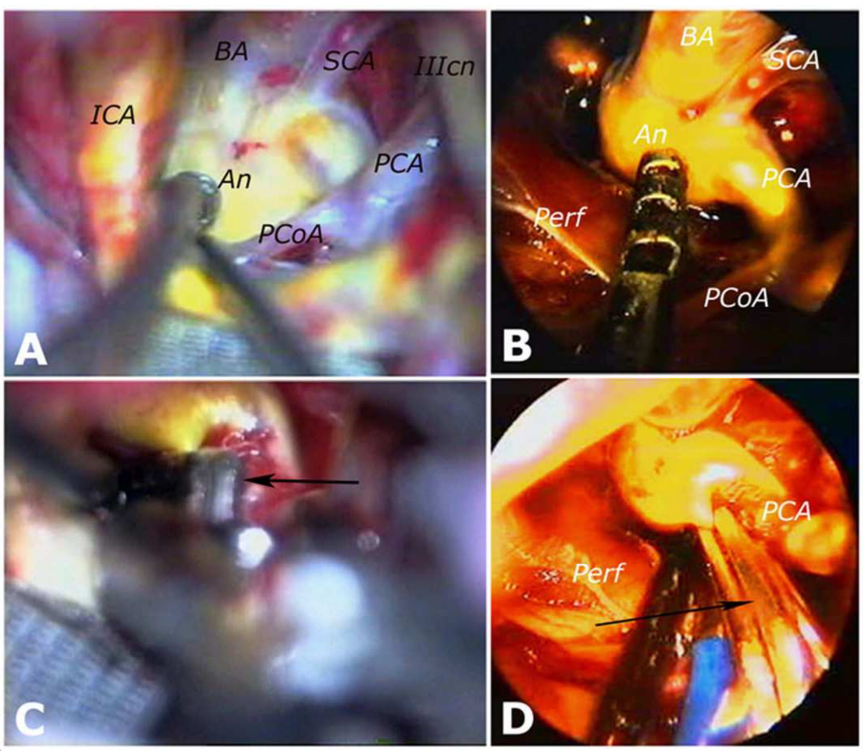

Fig. 12. Intraoperative images (same case of Fig.11): microsurgical images (A,C) and endoscopic images (B,D) performed during the endoscope-assisted microsurgical treatment of a basilar tip aneurysm through a right FTOZ approach; it is clear that the endoscope allows a better panoramic vision of the aneurysm (An) with minimal retraction of the internal carotid artery (ICA) and of the short posterior communicating artery (PCoA) from which a critical perforator (Perf), not visible in pure microscopic vision, enters the mesencephalon; the parental basilar artery (BA) with its distal branches, superior cerebellar artery (SCA) and posterior cerebral artery (PCA), are also better controlled by the endoscope; the scope also allows a better control of the distal portion of the clip (arrows).

2.2.4 Retrolabyrinthine presigmoid approach

The retrolabyrinthine transpetrosal presigmoid approach [Lawton, 1997; Motoyama, 2000] has been used in 6 cases of middle basilar artery aneurysm (lesions located at the junction of the basilar artery with anterior inferior cerebellar artery-AICA), none of which was a giant lesion.

The most important point in preparing this approach is the preservation of the labyrinth; in 2 cases we violated the labyrinthine bone with post-operative hearing troubles. This approach gives a tangential sight of the middle basilar trunk and allows an adequate clipping of small and medium sized aneurysms, but provides a very narrow surgical corridor which is not useful for more complex lesions (Figure 13).

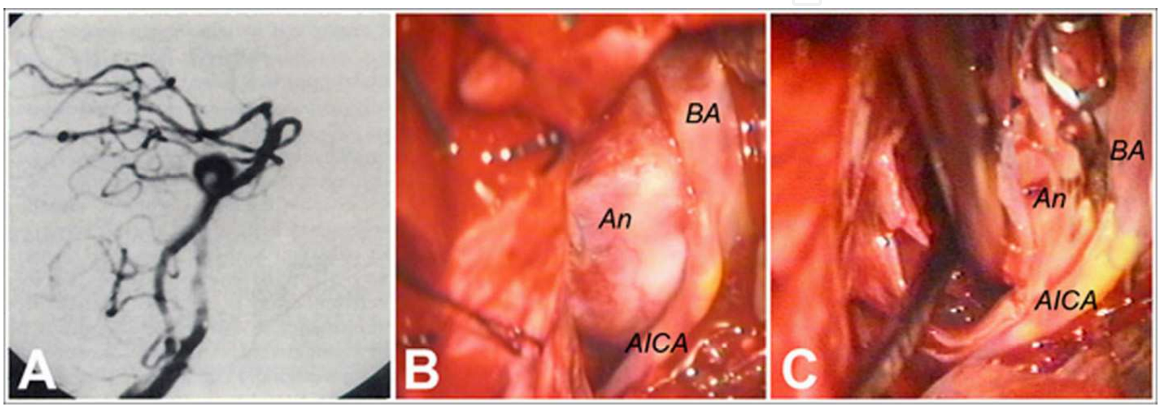

Fig. 13. Preoperative angiography of a large partially thrombosed middle basilar aneurysm (A); intraoperative view of the intact aneurysm (An), exposed through a right retrolabirinthine transpetrosal presigmoid approach, which allows a tangential vision of the lesion originating from the junction between the basilar artery (BA) and the anterior inferior cerebellar artery (AICA) (B); intraoperative image: the aneurysm has been clipped at the implant base and the sac completely opened (C).

2.2.5 Combined transpetrosal approach

The combined transpetrosal approach [Kawase, 1985; Seifert, 1996; Seifert, 2003] has been used in 10 cases: 5 complex middle basilar arteries aneurysms (2 of them were giant ones) and 5 aneurysms located in the vertebro-basilar junction (VBJ).

We prepared this approach as described by Fukushima and Sekhar [Harsh, 1992; Fukushima, 1996]. Nowadays we prefer using this approach to treat middle basilar/AICA aneurysms instead of the retrolabyrinthine approach, because it allows a wider working room, where multiple clips can be apposed to treat more complex lesions, and always allows the preservation of the labyrinthine bone (Figure 14). Moreover, we have used this approach in case of junctional aneurysms, specially when the VBJ was high located.

2.2.6 Far lateral approach

The far lateral approach has been used in 30 cases: 8 aneurysms in the VBJ, including 3 giant ones, and 22 aneurysms located in the intradural VA (VA/PICA aneurysms), including 3 giant lesions. Multiple variations of this approach have been described [Salas, 1999]: it allows the complete control of the VA along the full length of its intradural portion until the basilar junction.

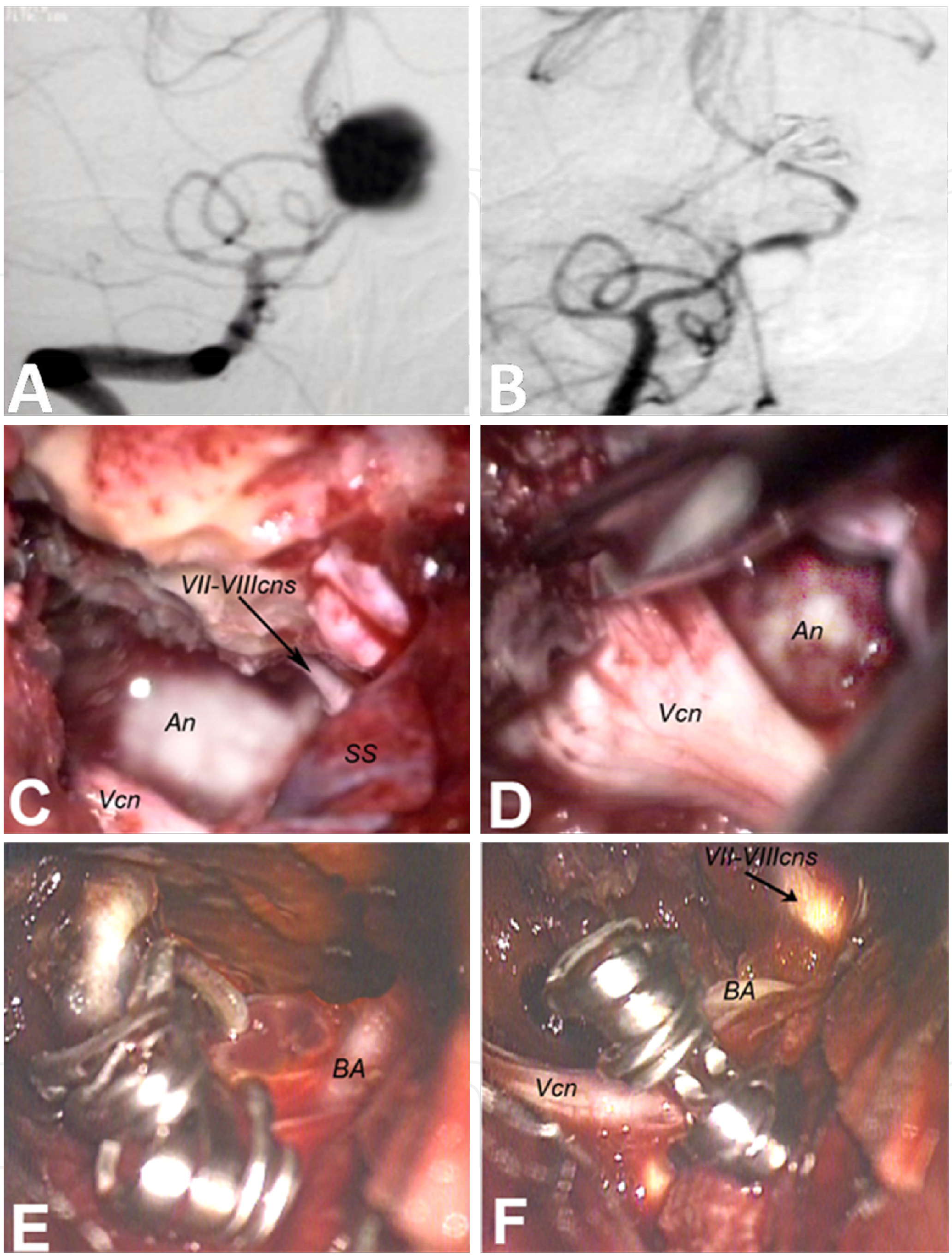

Fig. 14. Preoperative and postoperative angiography of a very large BA/AICA aneurysm, approached through a right combined transpetrosal presigmoid approach (A,B); intraoperative images: the aneurysm (An) is visible after opening the dura located anterior to the sigmoid sinus (SS) deeply embedded between the complex of seventh and eight cranial nerves (VII-VIIIcns) and the fifth cranial nerve (Vcn) which appears flattened by the underlying aneurysm (C,D); intraoperative images: after the definitive clipping with multiple differently shaped and sized clips, the sac was opened, thus highlighting its complete exclusion with preservation of the parental basilar artery (BA) (E,F).

We performed the approach as originally described by B. George, who defines it as the "postero-lateral" approach to the cranio-vertebral junction [George, 1980; Heros, 1986; George, 2000].

The far lateral approach is the ideal choice to treat the VBJ aneurysms because it provides a tangential view of the junction itself with minimal or no cerebellar retraction (Figures 15 and 16). This is specially true when the junction is not very high positioned: in case of high located VB junction or in case of evident platybasia a combined transpetrosal approach is preferable.

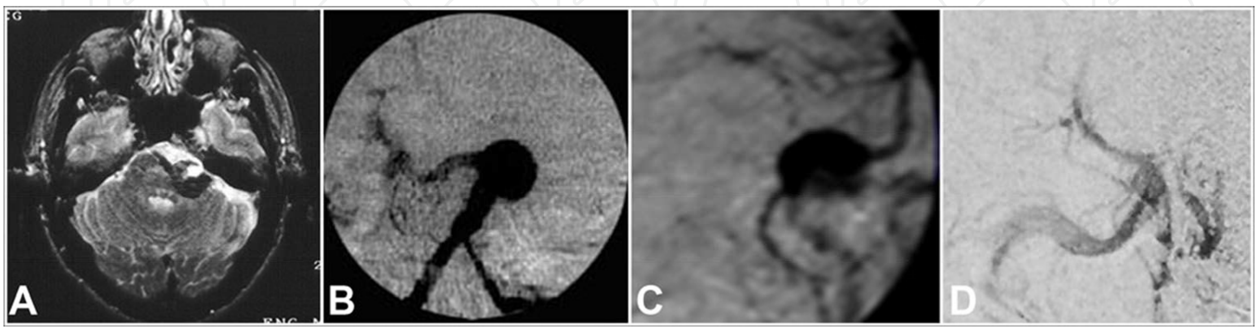

Fig. 15. Preoperative CT scan (A), preoperative angiography (B,C) and intraoperative angiography (D) of a very large aneurysm located at level of the vertebro-basilar junction and prevalently located in the lower portion of the left ponto-cerebellar angle because of the dolichotis deviation of the vertebrobasilar arteries.

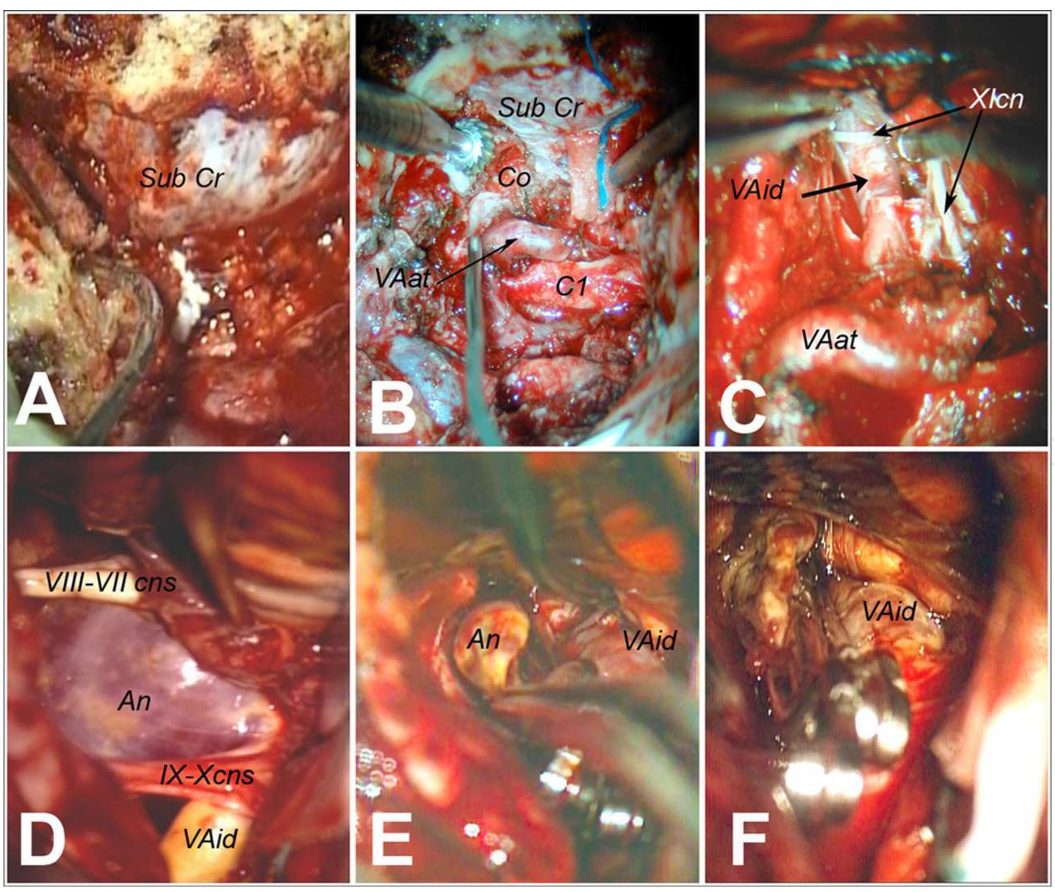

Fig. 16. Intraoperative images of the same case of Fig.15: the lesion was exposed through a right far lateral approach; after skeletonizing the squama occipitalis, the occipital condyle,

the lamina and lateral mass of the first cervical vertebra (C1), a suboccipital craniectomy (sub Cr) is perfomed (A) and the condyle (Co) is partially drilled to expose the atlantal portion of vertebral artery (VAat) (B); after opening the dura, the eleventh cranial nerve (XIcn) and the intradural portion of the left vertebral artery (VAid) are exposed (C); the dissection is superiorly directed and the cerebellar hemisphere is medialized thus displaying the aneurysm (An) embedded between the inferior cranial nerves (IX-X cns) and the facio-uditive complex (VIII-VIIcns) (D); the aneurysm has been clipped with two long straight clips apposed in "tandem" fashion and the sac was opened and shrinked with bipolar coagulation (E,F).

It is also the approach of choice for aneurysms located in the intradural vertebral artery (VA/PICA region), where it may be necessary to dissect the implant base of the aneurysmal wall from the inferior cranial nerves and from PICA; this method provides the complete control of the posterolateral aspect of this kind of aneurysms which is, on the other hand, the real necessity because the VA has not important perforators in its anterior wall in this portion (Figures 19 and 20). This approach allows complete exposure of the implant base of the aneurysm and of the parental artery also in case of lesions deeply located in the midline (Figures 19 and 20) or in case of very large lesions (Figures 17 and 18). Thereafter, it is not necessary, in our opinion, to use an extreme lateral approach as suggested by other authors [Day, 1997].

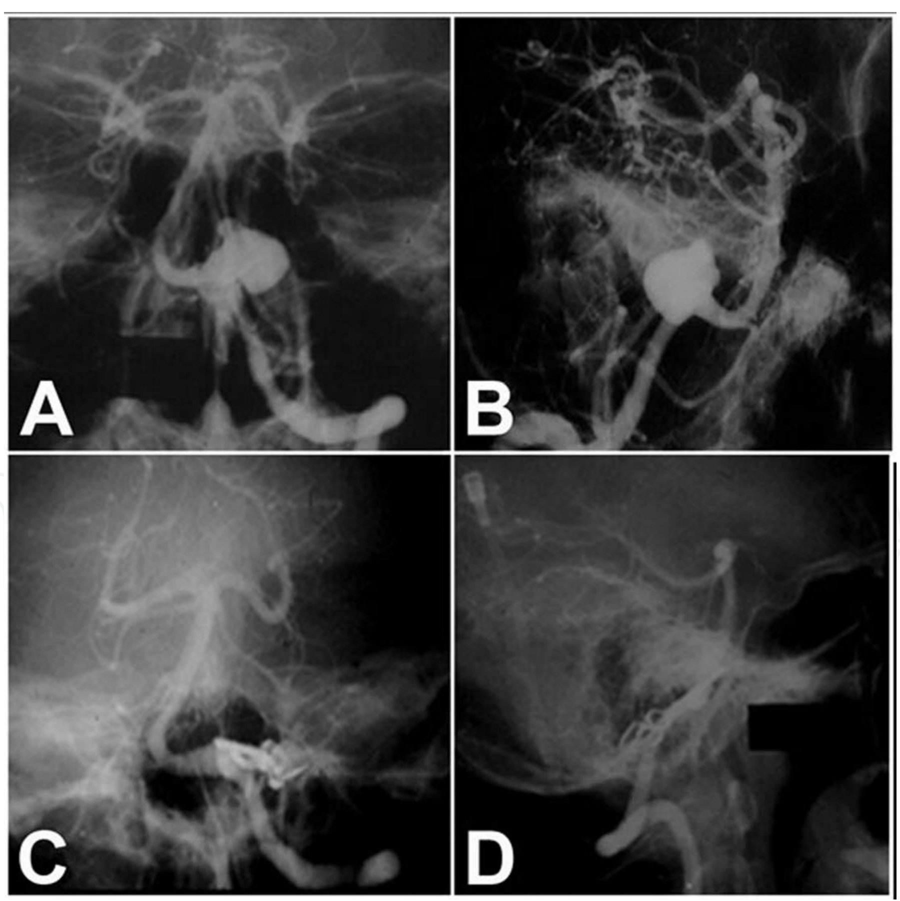

Fig. 17. Preoperative (A,B) and postoperative angiography (C,D) of a multilobulated very large left sided VA/PICA aneurysm.

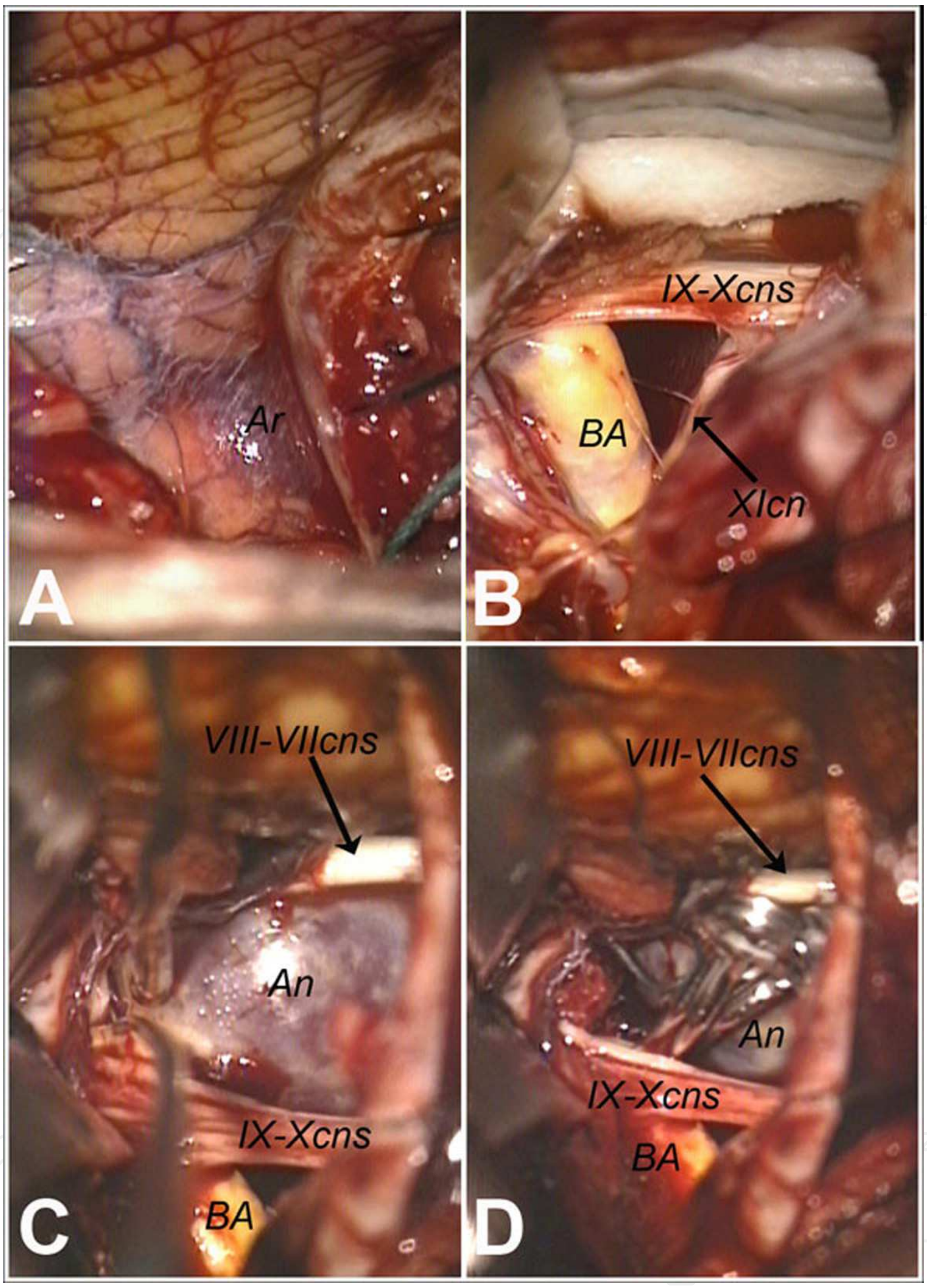

Fig. 18. Intraoperative images of the same case of Fig.17: the lesion was exposed through a left far lateral retrocondylar approach; after opening the dura mater of the posterior cranial fossa, the arachnoid (Ar) of the lateral inferior perimedullary cistern is opened and the spinal accessory nerve (XIcn) as well as the glossopharingeal and vagus nerves (IX-Xcns) and the intradural vertebral artery are exposed (A,B); the cerebellar hemisphere is medialized, evidentiating the aneurysm (An) between the inferior cranial nerves (IX-X cns) and the facio-uditive complex (VIII-VIIcns) (C); the aneurysm has been clipped with two clips parallel to the vertebral artery (D).

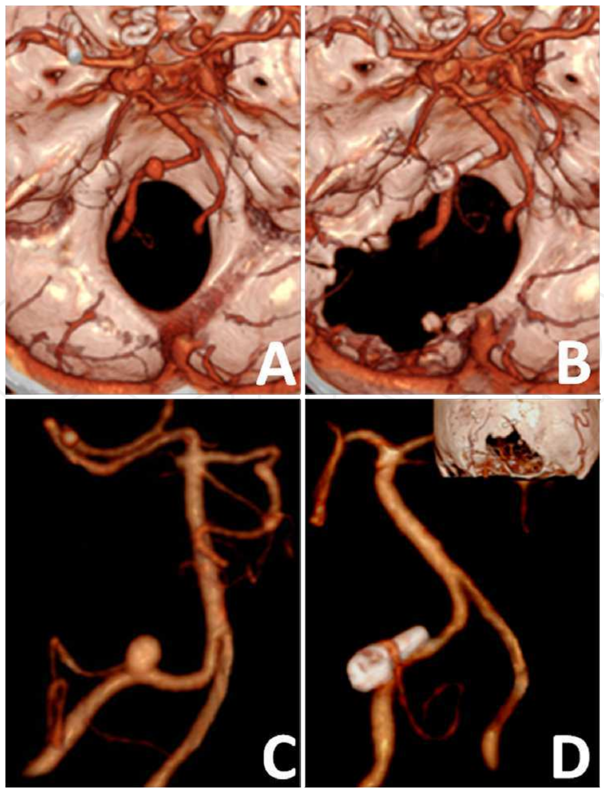

Fig. 19. Preoperative (A,B) and postoperative (C,D) 3D angio-CT reconstructions of a left VA/PICA aneurysm reached through a left far-lateral supracondylar approach. Because of the dolichotis course of the left vertebral artery, the aneurysm was deeply located at the level of the midline; it was exposed and treated with a limited bone removal of the occipital squama, without drilling of the occipital condyle.

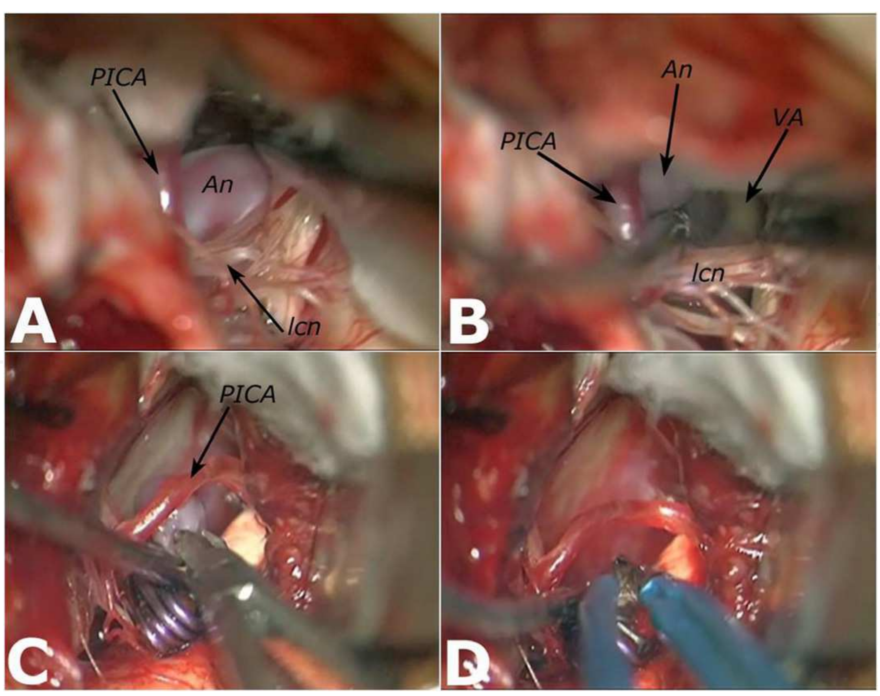

Fig. 20. Intraoperative images of the same case of Fig.19: the aneurysm (An) was exposed through a left far-lateral supracondylar approach, which gives a tangential view of the

aneurismal implant base and allows its dissection from the PICA and the lower cranial nerves (lcn) (A). The aneurysm is mobilized to visualize the prejunctional course of the VA (B). The clip was positioned parallel to the course of the VA, preserving the PICA: thereafter the sac is opened with microscissors and shrunk with bipolar coagulation (C,D).

2.2.7 Subtemporal approach

The sub-temporal approach has been used in the treatment of 5 aneurysms located in the P1/P2 and P2/P3 tracts of the PCA (4 of them were giant lesions) and of 3 aneurysms located in the distal portion of the SCA (none of them was a giant one).

To gain a wide subtemporal working room it may be necessary to dissect the vein of Labbè subpially to avoid stretching of the vein itself which can leave postoperative infarctions. To highlight the distal portion of PCA/SCA it is necessary to section the medial tentorial edge; this maneuver has to be performed posteriorly to the entrance of the 4th CN into the tentorium itself (Figure 21).

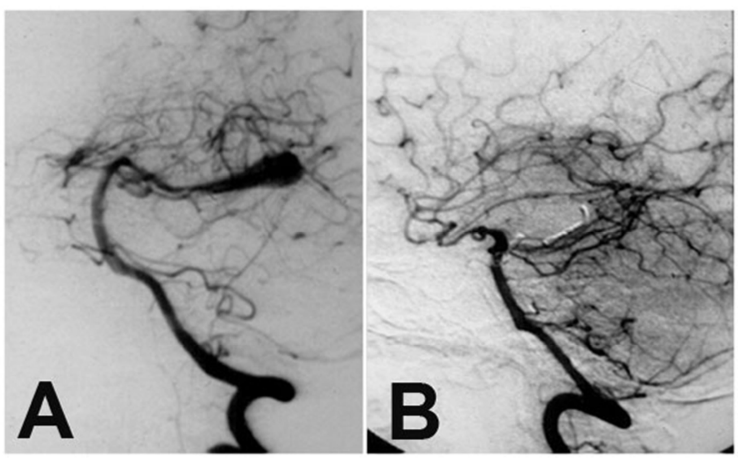

Fig. 21. Preoperative(A) and postoperative angiography (B) of a giant partially thrombosed aneurysm of the P2-P3 tract of the right posterior cerebral artery.

It has to be remarked that in three cases of giant massively thrombosed aneurysms of the distal portion of the PCA, the lesions were excluded by trapping with no additional postoperative deficit (Figures 21 and 22).

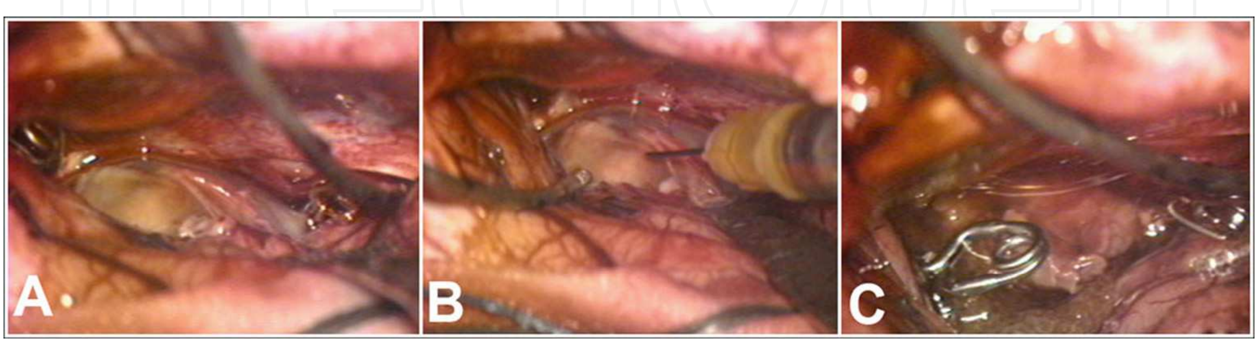

Fig. 22. Intraoperative images of the same case of Fig.21: the lesion was treated through a right subtemporal approach; the temporal lobe is retracted and the aneurysm exposed and trapped between two clips (A), evacuated (B) and completely opened (C).

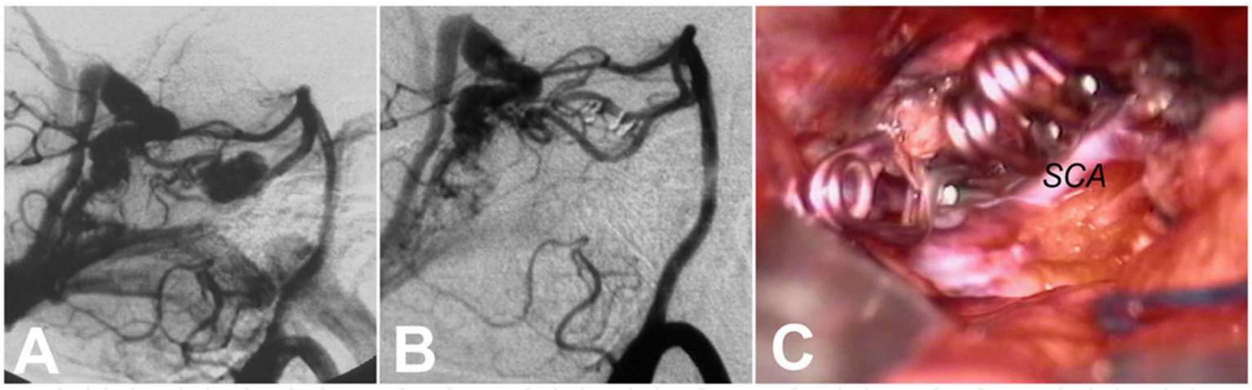

Fig. 23. Preoperative(A), postoperative angiography (B) and intraoperative image (C) of a large aneurysm of the distal portion of the superior cerebellar artery (SCA), excluded with multiple cerebral clips thus preserving flow in the parental artery. In the angiograms it is visible an artero-venous malformation partly irrorated by the SCA, where the aneurysm was located, which was successively treated by a suboccipital approach.

2.2.8 Retrosigmoid approach

The retrosigmoid approach has been used to treat a giant completely thrombosed aneurysm located in the premeatal portion of the AICA (Figure 24) and of an aneurysm of the labyrinthine artery, intrameatally located and thus requiring the drilling of the posterosuperior wall of the meatus to be exposed (Figure 25) [Zotta, 2011]. It has also been used in 1 case of BA/AICA aneurysm, but for this kind of lesion this approach seems inadequate because it only provides a narrow opening with an angle of attack parallel to the petrous bone with a limited exposure of the anterolateral wall of the basilar tract.

2.2.9 Suboccipital approach

The suboccipital approach has been used in the treatment of 2 aneurysms located in the distal portion of the PICA. The telovelar corridor has allowed to clip an aneurysm deeply embedded into the lateral recess of the fourth ventricle (Figures 26 and 27) [Kellogg, 1997; Mussi, 2000].

3. Discussion

The impressive advances of the endovascular technique have progressively shifted the management of intracranial aneurysms away from direct microsurgical clipping. Both the International Subarachnoid Aneurysm Trial (ISAT) [Molineux, 2001] and the International Study of Intracranial Aneurysms (ISUIA) [ISUIA, 1998] have reported better outcomes with endovascular coiling if compared with microsurgical clipping. In any case, the conclusions of these studies are significant only for aneurysms whose anatomy was suitable for both techniques and this is not the case for most of posterior circulation aneurysms. Only 58 patients from the cohort of 2143 patients enrolled in the ISAT harboured vertebro-basilar aneurysms and among the 7416 excluded patients, those with posterior circulation aneurysms had an anatomical configuration not equally suitable for both clipping and coiling or had factors excluding therapeutic equipoise. Also data regarding vertebro-basilar aneurysms reported in the ISUIA showed an apparent therapeutic advantage of coiling only in the treatment of large and very large (13-24 mm in diameter) aneurysms. Thereafter, neither ISAT nor ISUIA have definitively reported a clear evidence that endovascular therapy is superior to microsurgical clipping for posterior circulation aneurysms. A revision of follow-up data from ISAT has highlighted decreased rebleeding and potentially more favourable results for younger patients (less than 40 year old) treated by microsurgery [Mitchell, 2008].

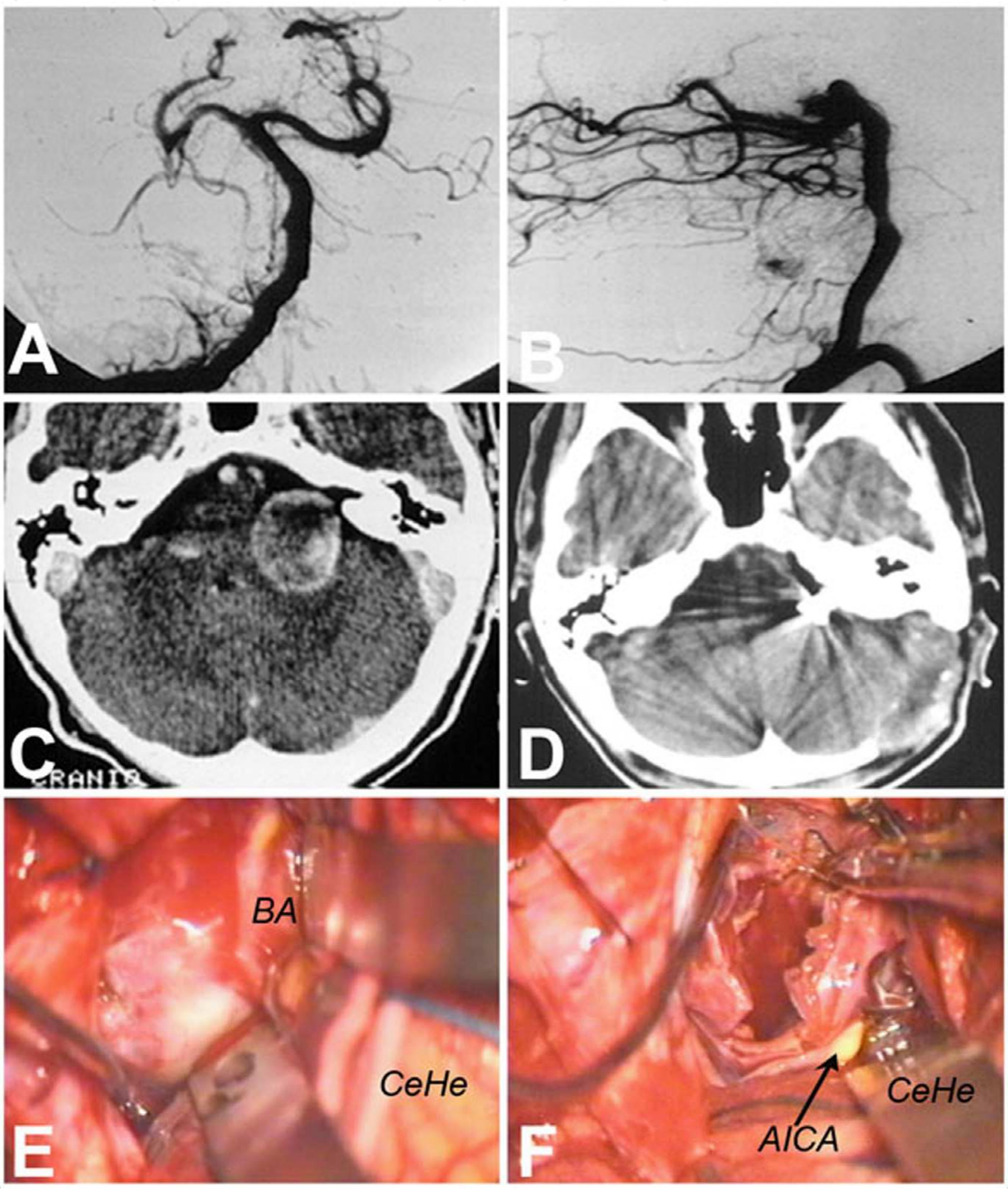

Fig. 24. Preoperative angiography(A,B), preoperative and postoperative CT scan (C,D) and intraoperative images of a giant thrombosed aneurysm of the AICA after its origin from the basilar artery (BA), which was clipped and opened through a left retrosigmoid approach. The aneurysm mimicked, clinically, a vestibular schwannoma and its exposure required a certain degree of retraction of the left cerebellar hemisphere (CeHe).

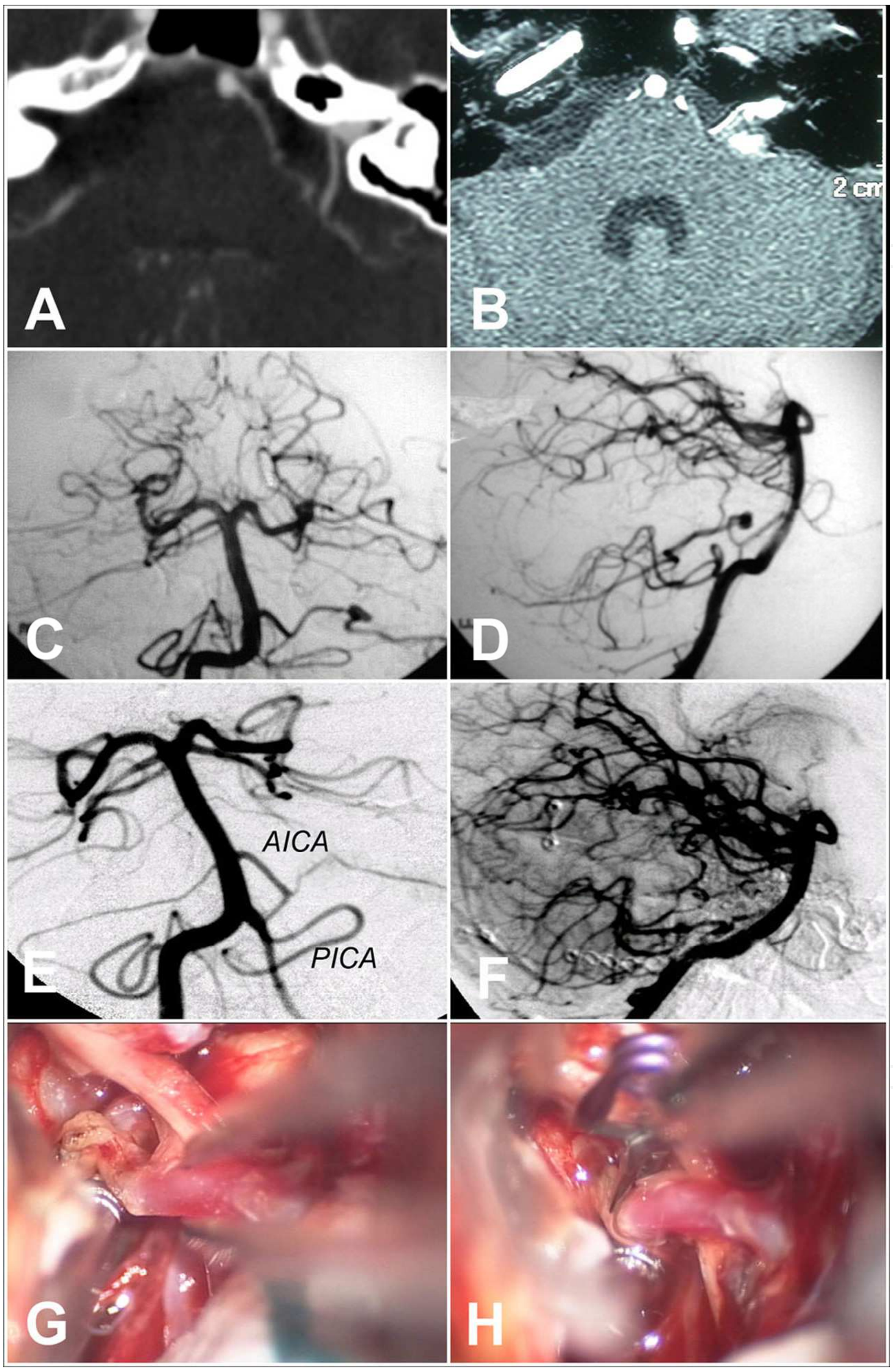

Fig. 25. Preoperative angio-CT (A), preoperative MRI (B), preoperative angiography (C,D), postoperative angiography (E,F) and intraoperative images of a distal AICA aneurysm, located intrameatally, which was treated through a left retrosigmoid approach; exposure of the aneurysmal sac required drilling of the posterior wall of the internal acoustic meatus.

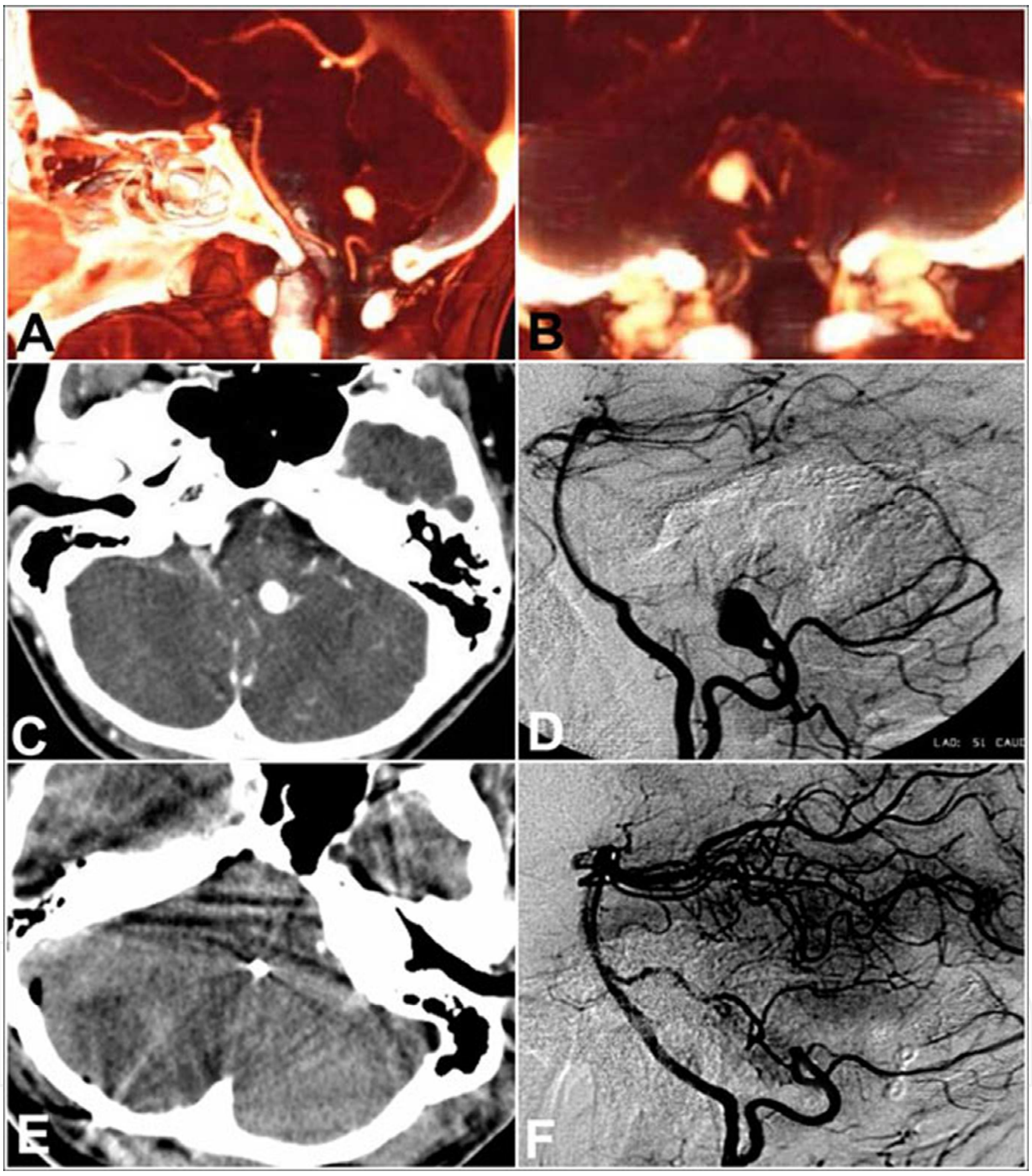

Fig. 26. Preoperative angio-CT sagittal and coronal reconstructions (A,B), preoperative angio-CT scan (C), preoperative angiography (D), postoperative CT scan (E) and postoperative angiography (F) of a large, wide based, aneurysm of the distal portion of the right PICA, deeply embedded into the left lateral recess of the fourth ventricle, which was approached through a suboccipital telovelar approach.

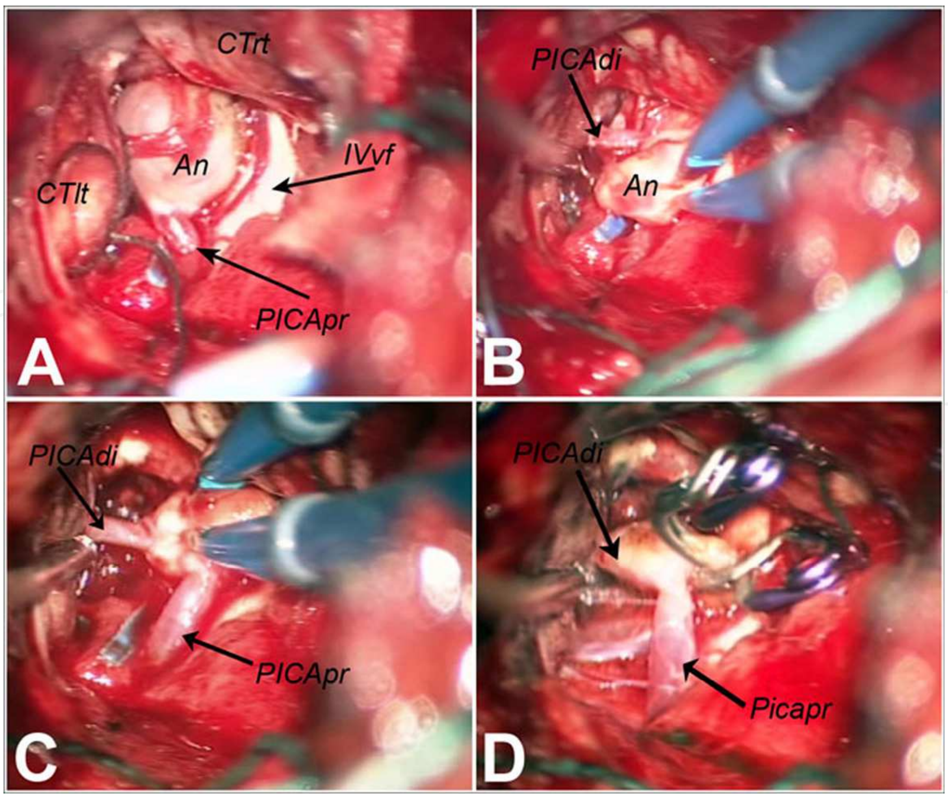

Fig. 27. Intraoperative images of the same case of Fig.26: the left cerebellar tonsil (CTlt) and the right cerebellar tonsil (CTrt) have been upward mobilized and divaricated to expose the floor of the fourth ventricle (IVvf) and the aneurysm (An), which presents an almost fusiform shape, with the proximal portion of the parental branch of the right posterior inferior cerebellar artery (PICApr) entering the lesion in full channel (A); the aneurysm is shrunk using the bipolar coagulator to reconstruct an implant base (B,C), where two embricated clips are definitively apposed, with preservation of flow in the post-aneurismal.

In the last two decades, new endovascular devices and special methodologies for device use have been introduced and reported, thus allowing the treatment of very complex cases. Wide-necked basilar tip aneurysms can be treated using two stents inserted from the basilar artery into each posterior cerebral artery in a Y-configuration to allow stent-assisted coil embolization [Chow 2004, Perez-Arjona 2004, Thorell 2005]; flow-diverting stents allow aneurysm occlusion without the addition of coils also in cases of wide-necked vertebro-basilar lesions [Lylyk 2009, Fischer 2011] (Figure 28). Several advances have been achieved with microsurgery, from the adoption of skull base approaches to the use of intraoperative digital subtraction angiography and indocyanine green angiography; use of intraoperative ultrasonography and neurophysiological monitoring may prevent ischemic complications; endoscopic assistance allows a better control of clipping (Figures 29 and 30). Indirect microsurgical treatment by revascularization and parental vessel occlusion and combined microsurgical and endovascular management allow the treatment of very complex aneurysms with satisfactory outcomes.

Recent papers have shown that microsurgery remains an important and unavoidable method of treatment, especially in cases of particularly located or shaped lesions [Fraser 2011, Sekhar, 2011]. The specific role of microsurgery remains essential and has not be abandoned also for posterior circulation aneurysms [Sanai, 2008].

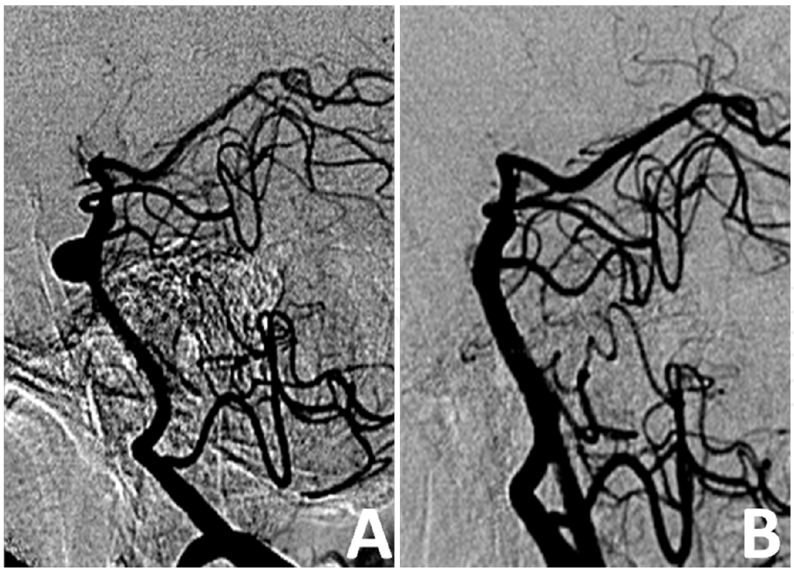

Fig. 28. Preoperative (A) and postoperative (B) angiography of a wide-necked mid-basilar aneurysm treated through flow diverter stenting.

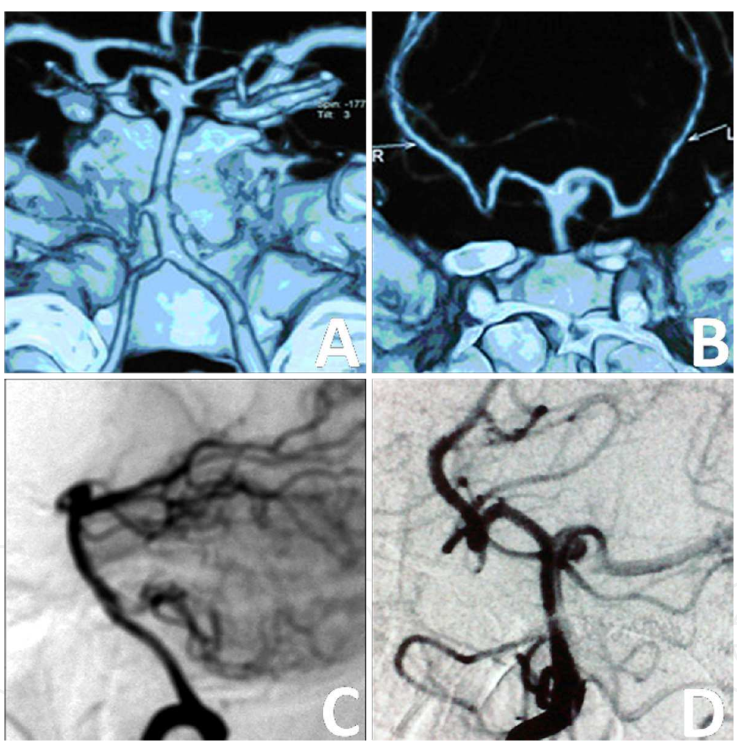

Fig. 29. Preoperative angio-CT reconstructions (A,B) and preoperative angiograms (C,D) of an aneurysm of the left PCA/SCA junctional portion of the basilar artery.

On the other hand, better surgical results can only be achieved in dedicated and specialized centers treating a high volume of cases, with a multidisciplinary cerebrovascular team where microsurgical and endovascular expertise cooperate in an integrated and collaborative way [Peschillo 2011].

In this chapter, the Authors present results and surgical approaches used in 144 patients harbouring 150 aneurysms of the posterior circulation, microsurgically treated over a period of 20 years (January 1990 – December 2010). This report is based on the experience of the Senior Author (RG), who has been involved in neurovascular surgery since 1978. Endovascular therapy was routinely introduced in our Institution at the end of the Nineties and consequentially almost all cases treated before 2000 were managed by direct microsurgical approach, while endovascular therapy has been progressively used more frequently during the second decade, so that the number of surgically treated patients has progressively reduced, while the percentage of surgical procedures for complex aneurysms has relatively increased.

A comparison between endovascular and microsurgical treatment of posterior circulation aneurysms goes beyond the aims of this paper and, because of the long period of time considered, some of the cases of the presented series would not be treated nowadays by direct microsurgery. However, from this experience, we have learned a number of lessons that can be summarized in some helpful suggestions..

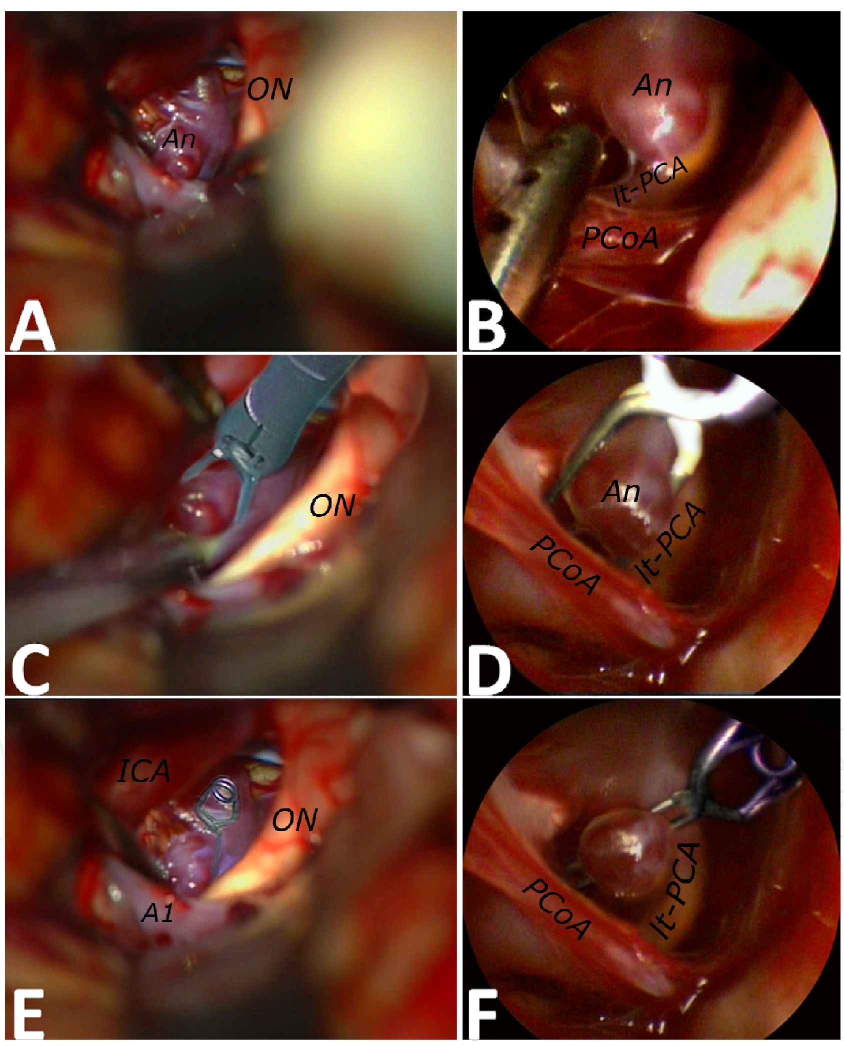

Fig. 30. Intraoperative images of the same case of Fig. 29. The aneurysm has been approached through a left pterional approach (the patient had been operated 1 year before elsewhere for a right ICA bifurcation aneurysm). The aneurysm was exposed under microscopic vision, passing in the corridor between ON and ICA: exposure of the lesion required excessive distortion of the ICA (A). A handheld upward-oriented 30°-scope was

used to explore the anatomical situation of the aneurismal sac and its relationship with the surrounding neurovascular structures (B). The aneurysm was clipped passing the clip applier through the corridor between ON and ICA, with the scope attached to a mechanical holder for control of surgical maneuvers (C,D). The final endoscopic control allowed to confirm patency of the left PCA which was not clearly visible under the microscope (E,F). [An: Aneurysm; ON: optic nerve; ICA: internal carotid artery; PCoA: posterior communicating artery; lt-PCA: left posterior cerebral artery; A1: A1 tract of the left anterior cerebral artery].

4. Expert suggestions

Each patient harbouring an intracranial aneurysm, both if located in the anterior or in the posterior circulation, has to be evaluated on individual basis by a cerebral vascular team with multidisciplinary expertise.

Decision making is essentially depending on aneurysms intrinsic features and patient's condition, but also patient's preferences and institutional specific expertise can influence the therapeutic choice. Location, morphology and size of the aneurysm, presence of branches originating from the implant base or from the sac, intraluminal thrombosis, atheromasic changes are all factors to be considered, as it is for patient's symptomatologies and comorbidities.

Treatment considerations are different for ruptured and unruptured aneurysms. There is no doubt that patients with ruptured aneurysms should be treated, because of the high incidence of rebleeding in the first days after the initial haemorrhage; aneurysms with a favorable dome-to-neck ratio (≥2) can be usually treated by coil; stent- or balloon-assisted coiling can be used for aneurysms with a relatively large neck (dome-to-neck ratio: 1.5-2); aneurysms with aberrant arterial branches and very small ones most frequently have to be treated by direct surgery; dissecting and fusiform aneurysms have to be treated by alternative or combined surgical techniques (i.e. diversion by-pass with surgical or endovascular parent vessel occlusion); flow-diverting stents can not be used in haemorrhagic patients because of the need to maintain these patients on dual antiplatelet therapy, which also inhibits other brain related surgeries (i.e. ventriculostomies or decompression). These general rules have especially to be applied to vertebro-basilar aneurysms. For unruptured aneurysms, the decision about to treat or to observe is crucial, also considering that posterior circulation aneurysms are more prone to rupture than their counterpart in the anterior circulation (ISAT). Flow-diverting stents can be used to treat not haemorrhagic aneurysms, also with unfavourable dome-to-neck ratio, when located in non-junctional areas as in the basilar trunk. When aneurysms are equally suitable for clipping or coiling, patient's preference has to be kept into account: patients who are unwilling to have seriated follow-up angiographies are not good candidates for endovascular treatment, as also are patients unable to such follow-up procedures because of contrast medium intolerance. Patient's age and location of the aneurysm represent the main factors to be considered in choosing the most appropriate treatment. Younger patients are preferred surgical candidates, while older ones and subjects with important comorbidities are preferably treated by endovascular technique. In our institution, lesions located in the distal vertebro-basilar branches are mostly treated by direct microsurgery, while basilar trunk, vertebro-basilar junction and vertebral artery aneurysms are mostly managed through an endovascular approach. Distal basilar lesions are treated by direct surgery when efferent branches are incorporated in the sac and when massive tumor-like expansive symptomatology is present. Also small aneurysms, especially if located in the tract between the origin of the superior cerebellar artery and the origin of the posterior cerebral artery are preferentially treated by microsurgery. Blister aneurysms, if occasionally found, are observed.

Nowadays we use dynamic multislice CT angiography (MSCTA) as primary preoperative study for all intracranial aneurysms, because this non invasive procedure provides quick 3D volumetric imaging with comparable sensitivity to rotational digital subtraction angiography (DSA), also allowing the disclosure of calcifications in the walls of the arteries or in the sac. Rotational 3D DSA is sometimes used, in addition, for more complex cases in which dynamic flow assessment is needed.

When the direct microsurgical treatment appears to be the best therapeutic option, the choice of the adequate approach constitutes the key point to get the best access and exposure to posterior circulation aneurysms. The use of the principles of the skull base surgery, which means to electively remove bone structures to minimize manipulation and retraction of critical perilesional neurovascular structures, allows the possibility to work in an adequate working room controlling both the lesion and the parental and efferent arteries from different angles of vision.

Most of distal basilar artery aneurysms can be exposed through a conventional pterional approach; in effect, this approach can be considered the first described skull base approach because the original description by Yasargil [Yasargil 1984] conceived drilling of the sphenoid wing exactly to avoid retraction of the fronto-temporal structures and to reduce manipulation of the neurovascular structures located in the basal cisterns. The cranio-orbital approaches are used only for most complex cases: wide lesions laterally directed require a fronto-temporo-orbital approach, while lesions located high to the biclinoidal line require a fronto-temporo-orbito-zygomatic approach. Aneurysms located in basilar trunk can be, as previously described, exposed through a retrolabyrinthine presigmoid approach or through a combined transpetrosal approach; nowadays we prefer this last approach because the first one provides a very small working room and exposes to higher risks of labyrinthine structures impairment; moreover, most of the small lesions that can be treated through the retrolabyrinthine approach are nowadays better managed endovascularly. On the contrary, the most complex lesions that have to be treated by direct microsurgery require a larger exposition, that only can be provided by the combined transpetrosal approach.

Even though, in the first period of our experience, we have used the combined transpetrosal approach in the treatment of vertebro-basilar junction aneurysms, nowadays we expose this kind of lesions exclusively through the far lateral approach, which is simpler and less challenging for the sigmoid sinus; the combined transpetrosal approach remains an option only in cases of very high located vertebro-basilar junction or of patients with evident platybasia. The far lateral approach remains the ideal approach also for vertebral artery aneurysms; when used for aneurysms, this approach does not require drilling of the condyle and thereafter occipito-cervical stabilization is not required.

Aneurysms located distally to the origin of the PCA and of the SCA are treated through the subtemporal approach, while distal AICA aneurysms are treated through the retrosigmoid approach, which is performed as described by Lawton [Quiñones-Hinojosa, 2006]; the median/paramedian sub-occipital approach is used for the treatment of distal PICA aneurysms [Kellogg, 1997; Mussi, 2000].

Nowadays we routinely use neurophysiological monitoring (BAEPs, SSEPs, MEPs) during posterior circulation aneurysms surgery. EEG monitored burst suppression is employed when temporary trapping or clipping of the parental vessel is performed [Quiñones-Hinojosa, 2004; Isley, 2009]. Monitoring of the facial nerve is performed when AICA's aneurysms are treated.

Neuronavigation is used whenever we perform a transpetrosal or a far lateral approach: it allows a safer localization of the venous structures (sigmoid sinus and jugular vein) that can be endangered during the preparation of the approaches as well as a safer exposition of the parental vessel and of the aneurysms itself.

Post-operative angiography is normally performed in any case, about six month after the surgical procedure.

5. Conclusion

The choice of the adequate approach constitutes the key point to get the best access and exposure to VB circulation aneurysms. The use of the principles of skull base surgery, which means to electively remove bony structures to minimize manipulation and retraction of perilesional neurovascular structures, allows the possibility to work in a wide working room thus controlling both the lesion and the parent and the efferent arteries, from different angles of vision. Obviously an adequate planning and a skilful experience with every possible additional technique and methodology are required for better outcomes.

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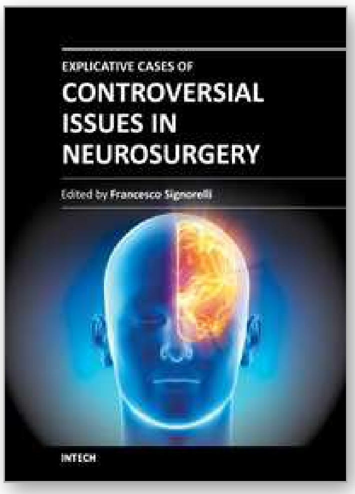

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University Campus STeP Ri
Slavka Krautzeka 83/A
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Phone: +86-21-62489820
Fax: +86-21-62489821